HUMAN VERBAL BEHAVIOR CONSIDERATIONS IN THE DESIGN OF VOICE ACTUATED HARDWARE SYSTEMS.

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THESIS

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IN THE
DESIGN OF VOICE ACTUATED HARDWARE SYSTEMS

by

Anthony Gerard Quartano

September 1977

Thesis Advisor: J.K. Arima

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The purpose of this experiment was to study the verbal behavior patterns of 15 P-3C and 15 non-P-3C aviators to determine a voice command vocabulary structure to be used with machine voice recognition hardware for implementation in the P-3C aircraft. Subjects were required to give a one or two-word verbal command response to a visual slide stimulus of a simulated P-3C pilot's display. There were

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Human Verbal Behavior Considerations in the Design of Voice Actuated Hardware Systems

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The purpose of this experiment was to study the verbal behavior patterns of 15 P-3C and 15 non-P-3C aviators to determine a voice command vocabulary structure to be used with machine voice recognition hardware for implementation in the P-3C aircraft. Subjects were required to give a one or two-word verbal command response to a visual slide stimulus of a simulated P-3C pilot's display. There were five distinct sets of slides, each portraying a different visual presentation. The subjects received the five sets in each of three blocks giving a total of 15 responses per subject. The verbal responses were recorded along with response latencies. Response latencies decreased for both groups as they progressed through the experiment with P-3C group always having the lower latency times. Both groups preferred using a two-word versus one-word command to describe changes on the visual display. Due to the two groups different aviation backgrounds there was no uniform preference for a specific syntactic structure of the command phrases. The implications of the findings for the design of systems using vocal commands are discussed.

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I. INTRODUCTION

With the advent of high-speed computer processing, coupled with electronic miniaturization techniques, technology has developed at an exponential rate. In order to keep up with ever-increasing technological advances, human factors research has done much work involving the efficient use of visual, auditory, and coordinated motor skill activities by human beings. However, these efforts and the human's capabilities as an operator are approaching their limits rapidly as advancements in and the numbers of complex systems and subsystems with which the operator must interface increase. For example, during World War II the P-51 fighter aircraft had nine subsystems and approximately 40 switches. The F-111 has 22 subsystems and over 220 switches (Reising, 1973).

In particular, aircraft crews are being presented with more and more information through their auditory and visual channels to which they must respond with coordinated motor processes. In conjunction with these demands the operator must also continue the primary task of either flying the aircraft within a specified envelope or keeping track of a tactical display.

As the demand for time sharing is increased between primary and several secondary tasks the load placed on the operator in this eye/hands busy environment will inevitably

lead to an operator overload and consequently degrade the primary task. A possible solution to reducing the time-sharing requirements and biomechanical manipulations is through the use of voice-actuated commands to operate complex subsystems while the operator maintains visual and motor concentration on the primary task.

Before going into the details of an actual voice command system a basic understanding of the human speech process is in order. The parts of the body that contribute to the human speech pattern are shown in Figure 1. Voiced sounds are produced when forced air from the lungs passes between the openings of the vocal chords. One example of a voiced sound would be when a vowel such as the letter /a/ is spoken. When the openings between the vocal chords are small, high frequency sounds are generated and when the openings are comparatively larger lower frequency sounds are produced. The vibrations of the vocal chords produce the fundamental frequency and its harmonics of the human speech pattern. Unvoiced sounds can be produced when air passes over sharp edges such as the teeth and becomes turbulent air flow. An example of an unvoiced sound would be the letter /s/. Unvoiced sound can also be generated when the vocal cavities are changed in shape and size as the position of the tongue, lips, and soft palate changes. The fundamental frequency is not present in unvoiced sound (Saib, 1974).

Energy levels, called formants, are used to analyze the complex waveforms produced in human speech. Formants

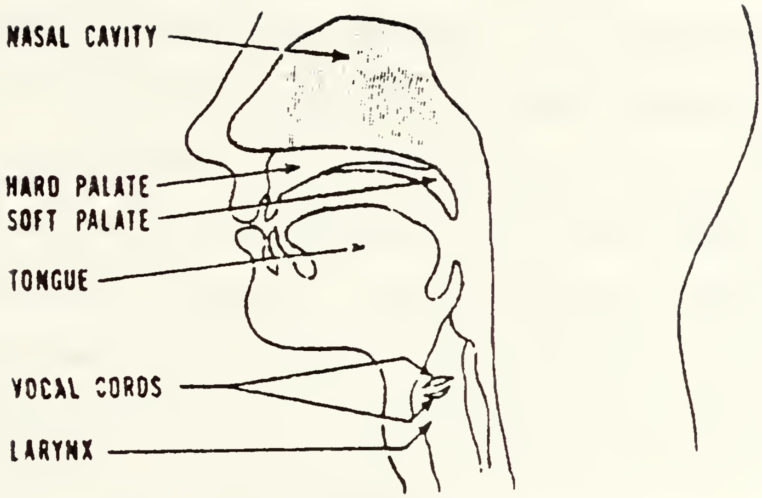


FIGURE 1. Human speech organs.
(From Reising, 1973, p. 5)

are frequencies which result from vocal cavity resonances. The first three formants can be used to describe most sounds. Therefore, the unique qualities of a sound can be determined using its formant characteristics (Flanagan, 1965). The fundamental frequency, usually designated F_o, lies between 75 and 400 Hertz (HZ). This frequency range can convey information which can be used to tell whether the speaker was male or female; whether the utterance was a question, exclamation, or flat statement; and if the speaker was under stress or not. The first formant, F_1, ranges between 200-1000 HZ; the second formant, F_2, ranges between 750-2700 HZ and the third formant, F_3, ranges from 2200 HZ and higher. Formant frequencies are dependent on vocal cavity size and therefore men, in general, generate lower formant frequencies than women and children (Saib, 1974). F_o and all three formants will be found in voiced speech but only F_2 and F_3 will be found in unvoiced speech.

The most basic sound element produced in the human speech pattern is called a phoneme. There are approximately 40 phonemes which describe all the English language sounds (Reising, 1973). For example, the /c/ in cow and the /k/ in keep are both described by the phoneme /k/. One approach to machine voice recognition is based on phoneme recognition.

In recent years much work has been done in the area of voice recognition by machine, and commercial uses are already in operation. Two companies which presently manufacture such equipment are Scope Electronics, Inc. of Reston, Virginia and Threshold Technology, Inc. of Delran, New Jersey.

A typical voice recognition and command system is an acoustic pattern classifier that produces a digital code output in response to a speech input (Glenn and Hitchcock, 1971). A simplified block diagram of a voice command system is pictured in Figure 2. The acoustic speech pattern is first converted into an analog signal by a microphone and amplifier (see Figure 2). The spectrum analyzer divides the speech input into frequency bands using 16 bandpass filters ranging from 200-5000 HZ. (Reising, 1973). The multiplexer and analog to digital converter sample the bandpass filters every 1/60 second with each sample producing a 4-bit value (Coler and Plummer, 1974). Therefore a speech utterance of one second would produce $16 \times 4 \times 60 = 3840$ bits. The coding compressor compensates for the time it takes to utter the same word from different speakers or two utterances from the same speaker. The coding compressor eliminates redundant spectral data while reducing the spectral data generated by each voice command into a 120 bit pattern for input to the classifier (Glenn and Hitchcock, 1971). Prior to any machine recognition, a training period is required. This is accomplished by storing in machine memory at least five samples of the desired vocal command. During the actual voice recognition sequence, incoming voice commands are compared with the commands in memory and recognition is accomplished provided the correlation between memory and incoming commands exceeds a preset noise rejection threshold (Coler and Plummer, 1974).

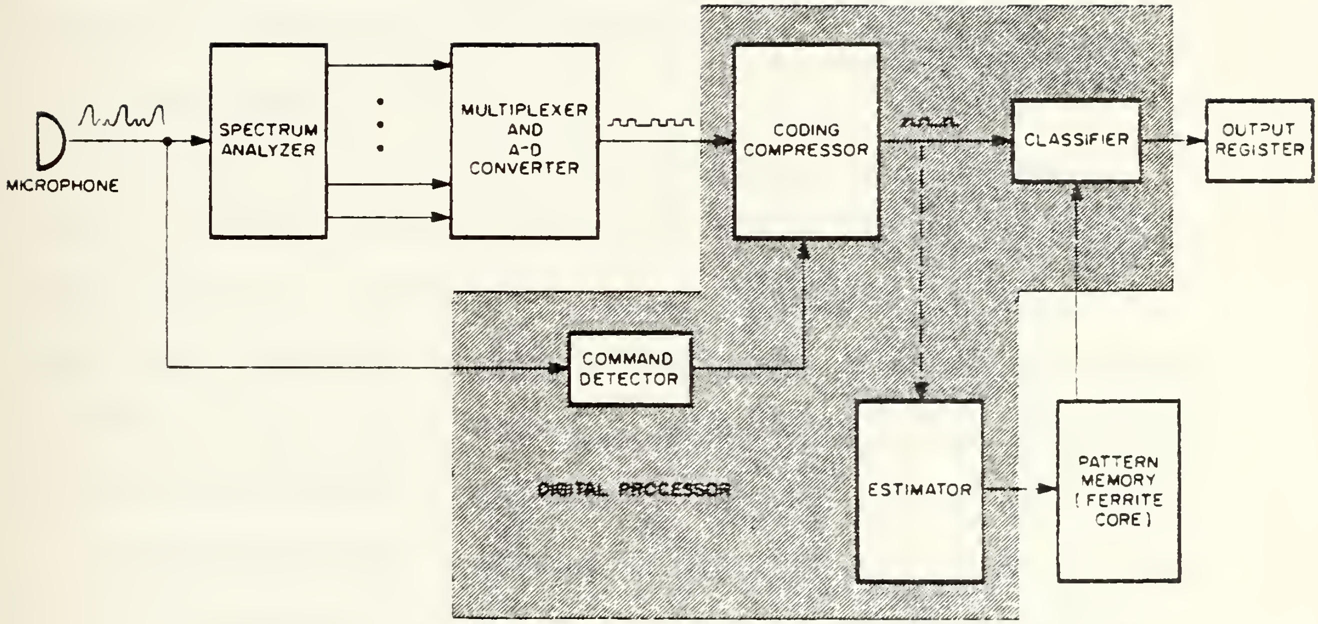


FIGURE 2. Simplified block diagram of a voice command system
(From Reising, 1973, p. 8)

The next step is to look at some of the advantages, disadvantages and applications of machine voice recognition.

Some of the advantages and problems involved in machine voice recognition can be studied by looking at some of the characteristics of speech itself. Speech is the human's primary and natural communication channel. The utilization of speech as a primary communication channel is increased when the language used to convey information is similar to the speaker's native tongue and is easy to pronounce. If words are difficult to pronounce or distortions of familiar vocabulary occur then the information transfer rate will decrease (Seibel, 1972).

Data shows that speech is potentially the highest capacity communication channel for human-to-computer input. (See Figure 3.) Although it is possible to have higher data input rates using special keyboards which input complex statements with one pushbutton, they are not very flexible and require extensive training on the part of the operator.

Another important feature of the speech channel is that it is independent of the visual channel and most of the voluntary motor activities. Speech communication can take place simultaneously with manual and visual tasks and thereby alleviate some of the load placed upon the eye/hand interface (Turn, 1974).

An example of this feature is the use of an automatic speech recognition system being used by cartographers for entering bathometric readings from smooth sheets into a

DATA RATES FOR MAN-TO-COMPUTER COMMUNICATION

Communication Mode	Rate (Words/sec.)	Remarks
Oral reading [9]		
Random words	2.1 - 2.8	Selected from 5000 word dictionary
Random words	3.0 - 3.8	Selected from 2500 most familiar monosyllable words
Nontechnical prose	3.9 - 4.8	
Repeating the same word	8.0 4.0	One syllable Two syllables
Silent reading	2.5 - 9.8	
Spontaneous speaking	2.9 - 3.6	
Handwriting [4]	.38 - .42	
Handprinting [4]	.22 - .53	
Typing [10]		
Skilled	1.6 - 2.5	Text (100 wpm - 150 wpm)
Inexperienced	.2 - .4	
Stenotype (chord typewriter) [11]	3.3 - 5	Typically 1/3 of the strokes of the typewriter
Operating touch-tone telephone [4]	1.2 - 1.5	10 buttons
Operating thumb-wheel input device	1.8 digits/sec.	Sequence of 10 digits [12]
Rotary dialing	1.54 digits/sec.	Sequence of 10 digits [12]

FIGURE 3. Data Rates for Human to Computer Communications (From R. Turn, 1974, p. 4)

digitizing computer (Scott, 1975). The automatic speech recognition equipment provides the cartographer the capability of entering depth readings through the voice channel without taking his hands and eyes from the X-Y coordinate positioning device used in this procedure. He normally enters the bathometric readings through a keyset and thereby breaks his concentration on the visual and manual processes involved in the task. The automatic speech recognition equipment described above was built by Threshold Technology, Inc. and had a capability of recognizing a vocabulary of 10 digits and five control words. System tests used 20 speakers uttering 360 words each, making a total of 7200 utterances. The machine showed a recognition accuracy of 99.375% (Scott, 1975), while .347% or 25 responses were misinterpreted by the machine. Out of those 25 responses, 11 were misinterpretations of the spoken digit "five" for the digit nine. In radio communications this has long been a problem, and has been alleviated by using the word "niner" instead of nine.

Speech can reveal information about the speaker such as physiological characteristics, physical condition, and emotional state (Williams and Stevens, 1972). Along this line the use of speech input allows checking the speaker's identity for security purposes. One specific application of automatic speech recognition in this area is an experimental system called Base and Installation Security System

(BISS) (Scott, 1975). Instead of manually entering, via a keyboard, a sequence of digits to identify oneself, the speaker would be identified by speaking the correct digit sequence and having the speech pattern being correctly identified as the person trying to obtain entry. A possible drawback of a system such as this would be the event when the speaker was sick or under stress and could not gain entry. However, consider the possible situation of an employee under gun point. In this stressful condition, entry by voice recognition into an access controlled room would be virtually impossible and a secondary identity system, such as closed circuit television, would most likely reveal unauthorized persons in the area.

The environment has a great effect on speech generation and speech propagation. Two of the forces that affect speech generation are vibrations and accelerations. However, the operation of manual input devices are also affected by these forces. Weightlessness has no effect on speech production (Turn, 1974), nor does it affect human motor movement. However, humans under the conditions of weightlessness are usually strapped in, thus restricting movement of the body and limbs.

Although speech generation is affected by vibrations and rapid accelerations these effects are not very substantial (Turn, 1974). It has been shown in experiments (Glenn, Gorden, and Moschetti, 1971; Wherry, 1973) that accuracy of

machine speech recognition decreased 5% when vertical sinusoidal vibration was increased from .05 to .3 g. When the subject received a sustained acceleration of 4 g, recognition accuracy decreased by 10%. A similar experiment was carried out on the effect of vibration on tactile input devices involving pushbuttons, rotary dials, and thumb-wheels which showed a 10% degradation of input rate at .8 g vibration level (Dean, Farrell, and Hitt, 1969).

Speech production and propagation are also affected by the composition of the atmosphere and ambient pressure (Turn, 1974). Speech propagation is also affected by ambient noise. However, hardware such as noise cancelling microphones and software changes to automatic speech recognition have alleviated many of these problems. A machine recognition accuracy of 97.15% was achieved in a laboratory environment with subjects breathing either oxygen or compressed air through an MBU-5 oxygen mask and using a standard noise cancelling microphone (Martin and Grunza, 1974). Ambient pressure changes such as high altitutde pose no significant problems, either, since it is possible to simulate high altitude conditions using microphone equalization techniques. Therefore, the machine can be trained at sea level for high altitude conditions without the use of an altitude chamber.

Martin and Grunza also state that, "Results indicate that existing aircraft microphone systems are adequate for voice control applications in a cockpit environment."

Since human speech is being considered as a primary communication channel, then some type of verbal learning will be needed on the part of the operator in order to communicate effectively with the voice recognition equipment. Because a visual, auditory, or vestibular stimulus will be responded to with a specific voice command, this interface could be considered as paired-associate learning. It has been shown (Adams, 1975) that if the meaningfulness of both the stimulus and response terms during paired-associate learning is high then the percentage of correct responses will be higher than for any other combination of stimulus and response pairs. Along these same lines it has been demonstrated (Adams, McIntyre, and Thorsheim, 1969) that using natural language mediators as compared to rote learning methods a higher percentage of correct responses can be achieved.

Not only must the individual words in a verbal command be taken into account but also how these individual verbal commands or words fit together to produce a completed task statement which is not only recognizable to the machine but which makes sense to the operator both syntactically and semantically. By applying principles of grammar or syntactic theory, strings of words can be structurally decomposed to reveal whether a word string is valid or invalid in accord with the given grammar. This is usually done by decomposing the word string into a tree structure

called a parse (Klinger, 1973). By examining the nodes of a parsing tree diagram of a particular command sentence, the verbal behavior of the human operator could be established and incorporated into the hardware to facilitate the human-machine interface. As an example of this, languages are arranged by taxemes, such as order. In the English language the nominative expression usually precedes the finite verb expression, however, in German the opposite is true. Therefore, the equipment should be programmed to accommodate the human operator in the natural form with which the human is most comfortable.

This will lead to a better human-machine interface that will reduce training requirements, enhance the reliability of the human in the system, and ensure that the proper performance (word commands) occurs under conditions of stress or information and response loads.

In summary, it should be pointed out that although there are still some problem areas associated with machine voice recognition, the advantages for voice recognition systems to aid the human operator certainly surpass some of the restrictions imposed on the human operator.

II. STATEMENT OF THE PROBLEM

The specific area that will be under investigation is the incorporation of a machine voice command system into a P-3C aircraft based at the Naval Air Station, Moffett Field. The National Aeronautics and Space Administration's Ames Research Center, located at Sunnyvale, California, owns and operates voice recognition equipment manufactured by Scope Electronics, Inc. The specific application will utilize voice recognition equipment to aid the pilot in the P-3C aircraft by using voice commands to enter and request data on the pilot's display (Figure 4) instead of using the present keyset entry mode (Figure 5).

In order to incorporate a voice command system to replace the keyset panel a command vocabulary is needed to replace the functions performed by the keyset panel. Two specific problems immediately arise. First, what are the best words to use, as far as the human operator is concerned, and how will this command vocabulary be developed? The second problem that arises is the compatability of the newly developed vocabulary with the constraints of the voice recognition machine. This thesis will address itself mainly to the problems of the human operator, although some of the hardware constraints will have to be taken into consideration in order to develop a realistic command vocabulary.

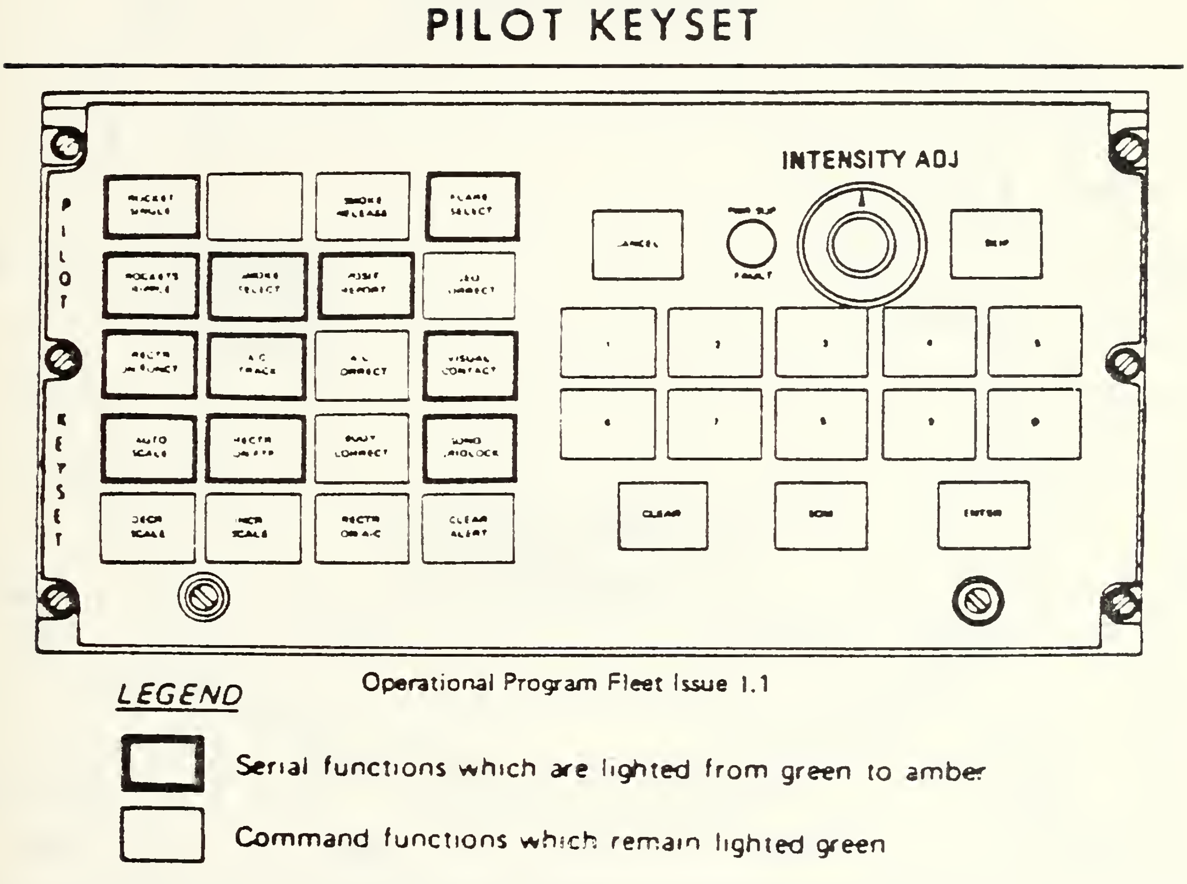


FIGURE 4. P-3C Pilot Display
(From P-3C NATOPS Flight Manual, NAVAIR 01-75PAC-1, FO23)

PILOT DISPLAY

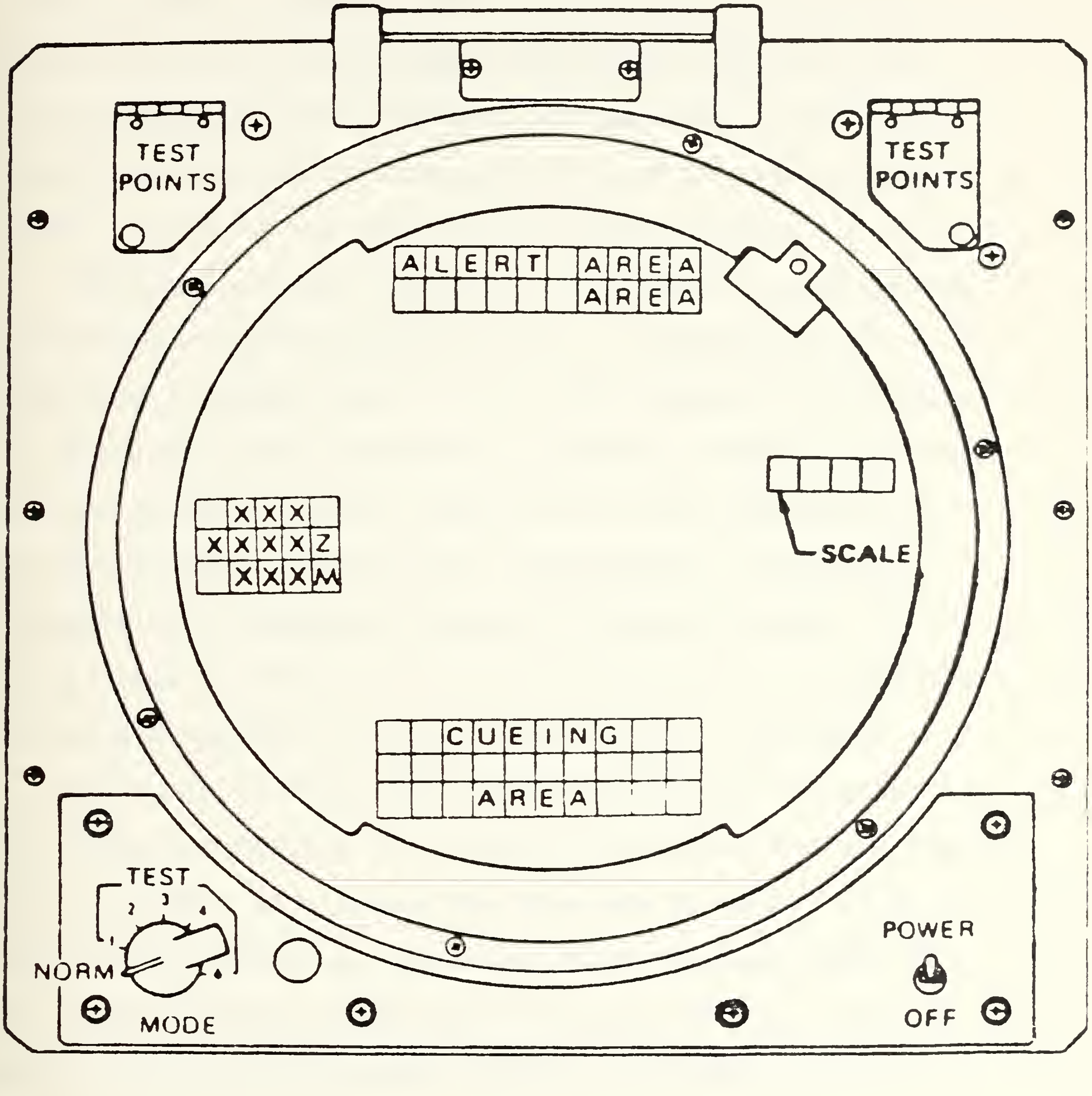


FIGURE 5. P-3C Pilot Keyset Panel
(From P-3C NATOPS Flight Manual, NAVAIR 01-75PAC-1, F023)

In the present state-of-the-art, machine recognition is limited to an isolated-word approach. Therefore, the pilot will be limited as to the number of words that can be used to utter a command. This is not a serious problem since aviators are thoroughly trained in communications intelligibility (Turn, Hoffman, and Lippiatt, 1974) and usually communicate in shortened phrases to reduce communication errors and to keep radio channels clear.

The approach that was used to determine an appropriate vocabulary was strictly empirical. An experiment was conducted to obtain the natural verbal behavior of experienced pilots under appropriate, simulated conditions. This was accomplished through the use of a slide presentation which simulated a P-3C pilot's environment. The slide presentation displayed a stimulus situation (Gagné, 1970) which posed a problem of creative description to the subject in which a response of one or two words was required.

The subjects were from two distinct groups of aviators. One group was familiar with the P-3C aircraft and the other group was not. The reason for this was to gather data which would be used in designing future systems based on the verbal behavior patterns of the two groups. The P-3C group may provide responses based on previously learned principles and recognition of the stimulus problems. Accordingly, their verbal behavior might be biased. Therefore, in the implementation of the initial voice

command systems the verbal responses of the existing P-3C community should most likely be incorporated into the voice command system to reduce training and improve reliability of the system. On the other hand, the verbal responses of the non-P-3C group must be considered for the long-range implementation of voice command systems, since their verbal responses should be naive. As new personnel enter the P-3C environment than modifications to the system may become necessary in order to phase out biased vocabulary in favor of natural human responses. In a more general sense, the responses of the P-3C subjects could be classified as those that would be expected when an existing system is converted to a voice command system, and the responses of the non-P-3C subjects would be similar to those that would occur in the design of a completely new system.

III. METHOD

A. SUBJECTS

The subjects were 30 volunteer students at the Naval Postgraduate School, Monterey, California. All subjects were male officers. Subjects were required to have had some type of military aviation experience and 15 of the subjects were required to have had P-3C flight experience. The P-3C group was designated AVTYPE 1 and the non P-3C group was designated AVTYPE 2. Both groups averaged over 1000 flight hours in their respective aircrafts and the ranks of the subjects were either Lieutenants or Lieutenant Commanders. The volunteers received no payment or gratuities of any kind for participating in the experiment.

B. APPARATUS

The apparatus consisted of an acoustic-absorbing testing chamber with a 61 by 76 cm. opague glass section in one wall on which the visual stimulus could be rear projected to the subject from outside the testing chamber. A Kodak Ektagraphic slide projector, model AF-2, was used to project the visual stimulus to the subject. A Lafayette Instrument's interval timer was used to program slide presentations and blank periods. An intercom system was installed to provide two-way communications between the subject and the experimenter, who remained outside the

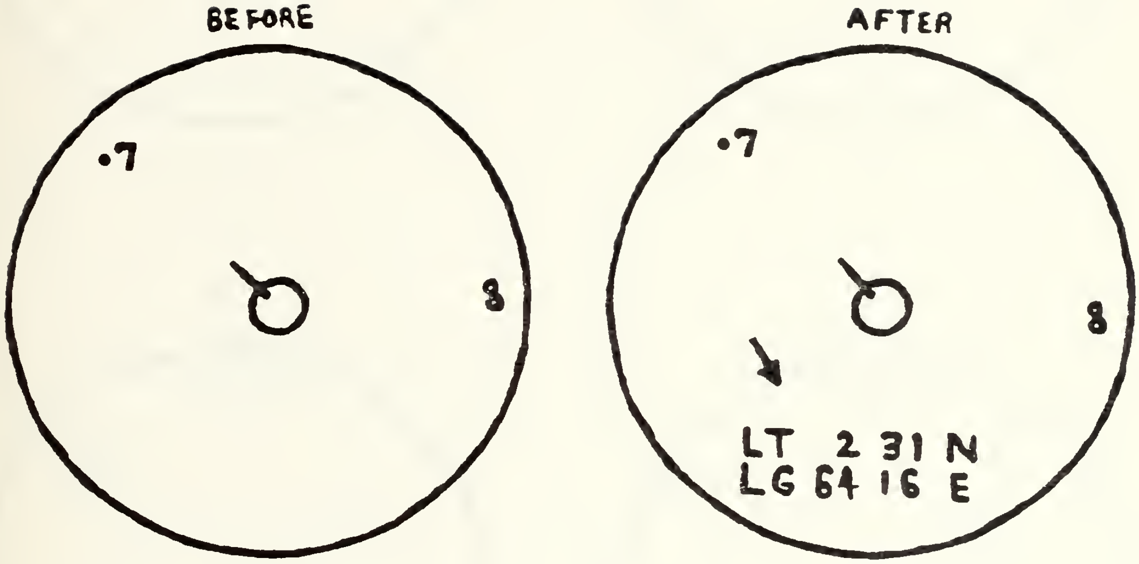
chamber during the conduct of experimental trials. A Robert's cassette tape recorder was used to record and present a taped briefing of the details of the experiment to the subjects, and a manually operated stop-watch was used to determine the verbal reaction time to the visual stimulus.

Stimuli consisted of five sets of slides which were made using a Kodak Ektamatic Visualmaker and had black backgrounds with white lettering to simulate the visual presentation on the P-3C aircraft's pilot display.

Three of the five sets of slides were made up of two slides while one set had three slides and the other four. Each set of slides represented one task for the subjects. The first slide of each set was labeled at the top with the word "BEFORE", and the last slide of each set was labeled at the top with the word "AFTER". (See Figures 6-10.)

C. EXPERIMENTAL DESIGN

Each subject was shown three blocks of slides with each block consisting of the five sets. The order of presentation was randomized within each block with the restriction that the last set of slides in each block could not be the first set of slides in the following block (see Figure 11). The independent variables were the two aviation groups, the three blocks of slides shown to each subject, and the five tasks involved during the slide presentations. The dependent variables were the response times to each of the five



A B

FIGURE 6. Slide Set "Position"

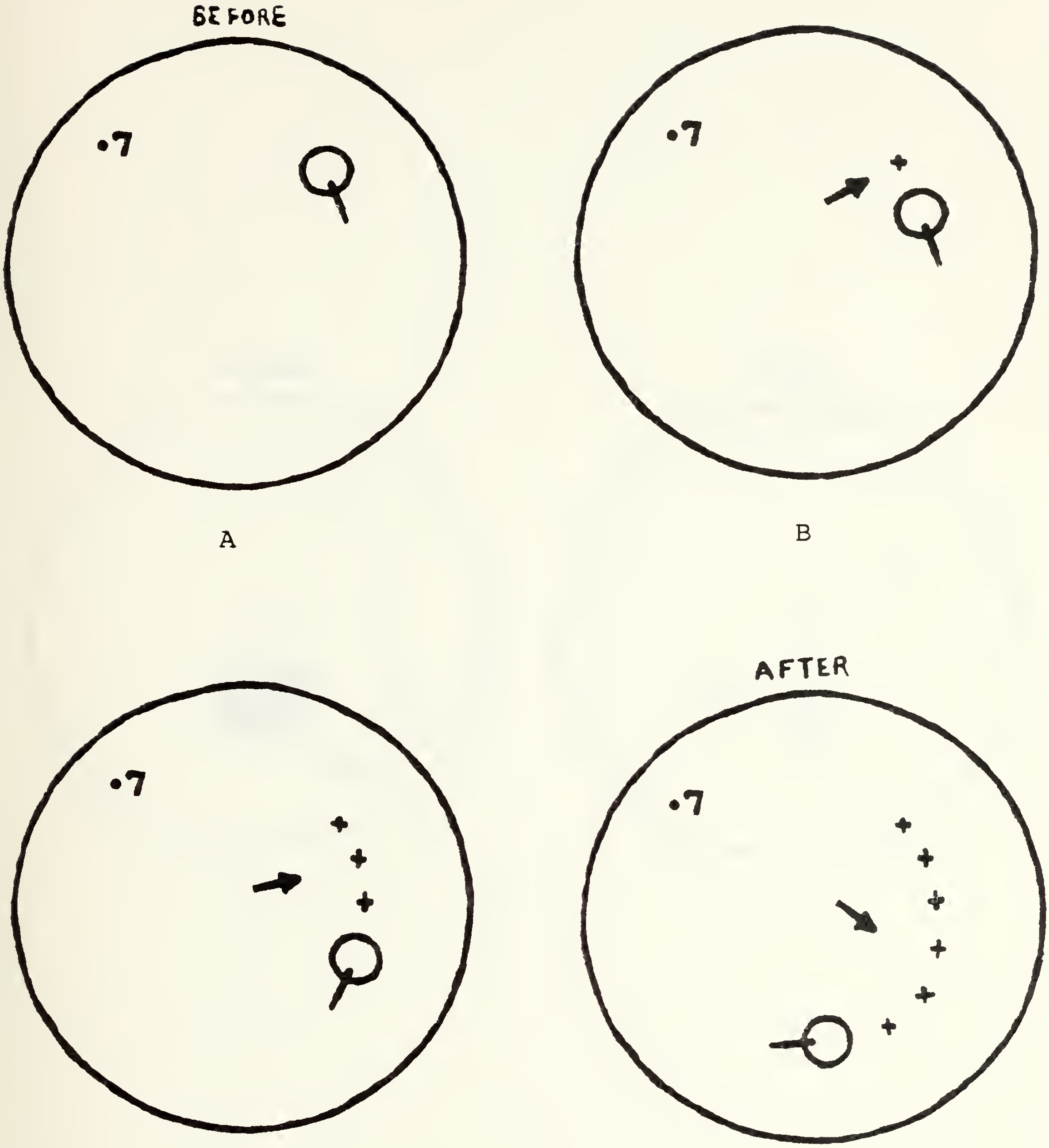


FIGURE 7. Slide Set "Track"

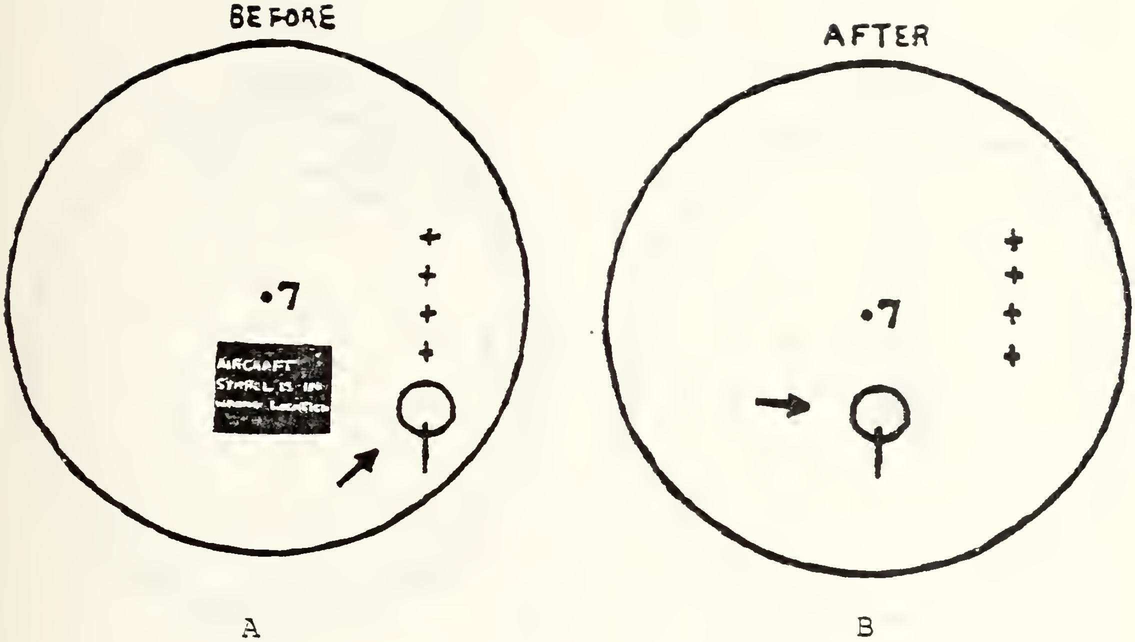
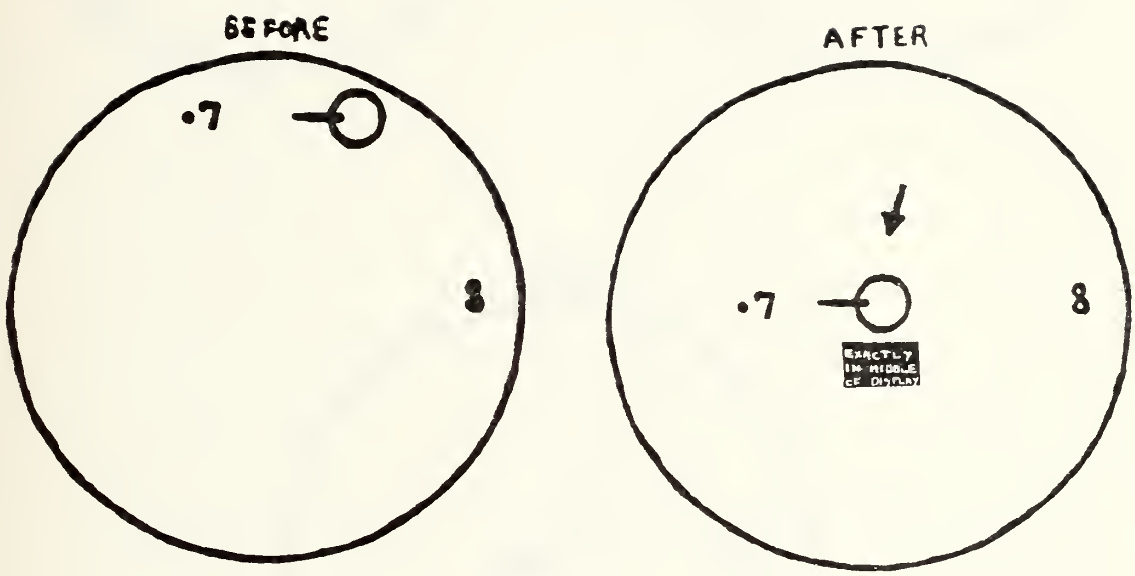


FIGURE 8. Slide Set "Correct"



A B

FIGURE 9. Slide Set "Center"

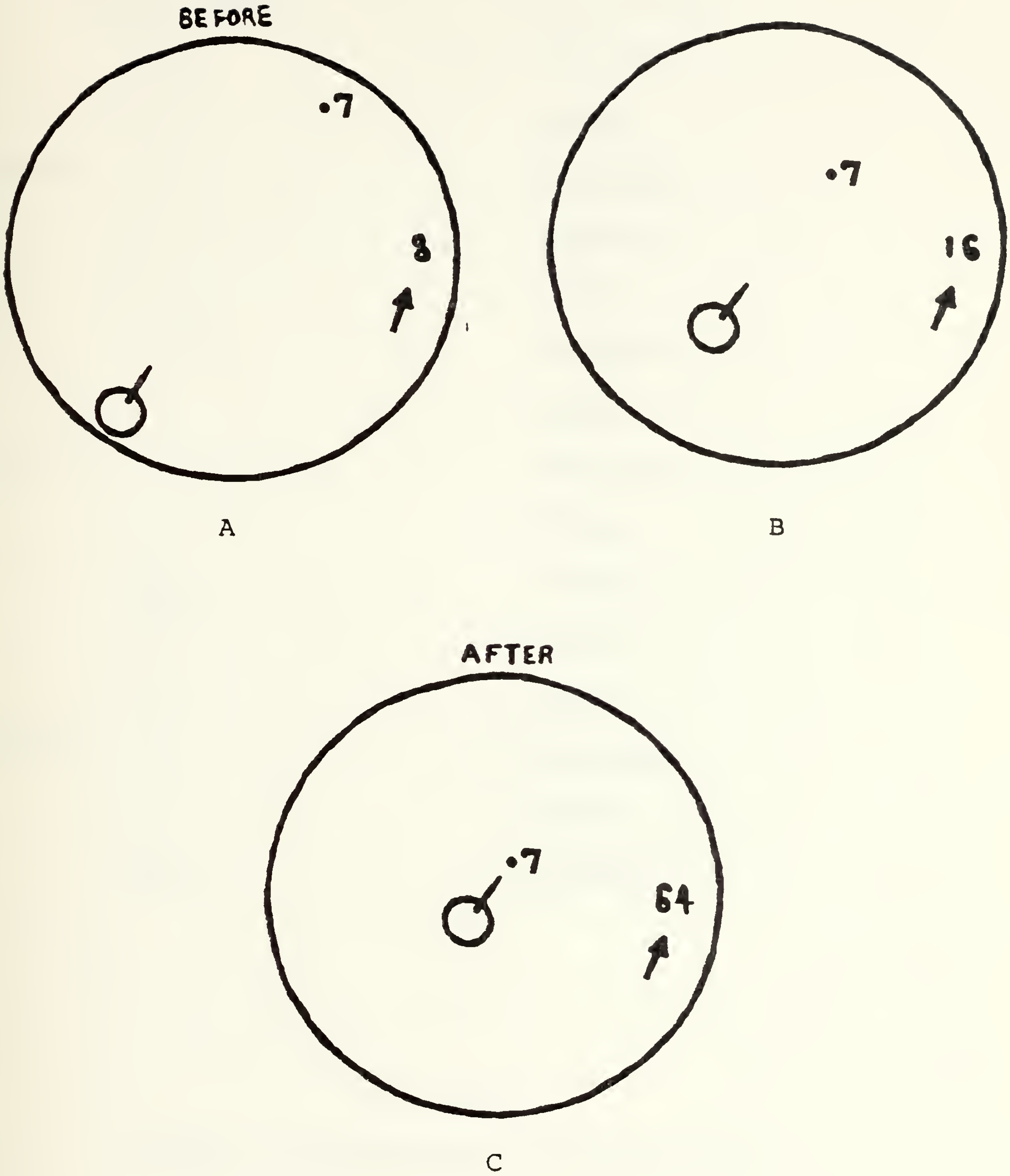


FIGURE 10. Slide Set "Scale"

Trial number		Slide Set
Block 1	1.	POSITION
	2.	TRACK
	3.	CORRECT
	4.	CENTER
	5.	SCALE
Block 2	6.	CORRECT
	7.	TRACK
	8.	POSITION
	9.	SCALE
	10.	CENTER
Block 3	11.	TRACK
	12.	SCALE
	13.	POSITION
	14.	CENTER
	15.	CORRECT

Figure 11

Order of Presentation of Slide Sets

distinct sets of slides and the verbal response content. A total of 15 responses per subject was required during the experiment for an overall total of 450 data points.

D. PROCEDURE

Each subject was greeted and escorted into the sound-absorbing chamber where he was asked to fill out a questionnaire pertaining to the subject's aviation experience (Appendix A). The subject was then seated in front of the viewing screen, which was approximately 61 cm. away. The experimenter remained with the subject. The subject was then shown a sample slide presentation in conjunction with a taped briefing describing the experiment and the subject's task. In essence, the subject was asked only to give a one or two-word verbal command which the subject felt would describe what had changed during each set of slides. A complete typed version of the taped briefing is located under Appendix B. When the taped presentation was concluded the subject was provided time to ask any questions.

After the question period the experimenter left the testing chamber and performed an intercom check with the subject. The subject was then presented with one blank slide prior to the start of the experiment. Then the subject was shown the 15 sets of slides. Each slide was shown for 10 seconds, based on the visual recognition study of Potter and Levy (1969). The first slide of each set was labeled at the top with the word "BEFORE" to represent

what the pilot would initially see. The subject then saw one or more slides to depict what would happen on the display when the pilot pressed a desired key function on the pilot's keyset panel. The last slide of each set was labeled at the top with the word "AFTER" to signify the end of that set and to cue the subject to give an appropriate one or two-word command which described what had changed on the slides. The changing part of the slides was indicated with a small white arrow. The subject then saw one blank slide before the next set of slides started. Therefore, the subject had 20 seconds to give a verbal response. The experimenter recorded the verbal response and reaction time on the Subject Data Sheet (Appendix A). After the last response was recorded, the subject was notified over the intercom system that the experiment was over. The subject was then asked to write down any comments about the experiment. Upon dismissal, subjects were requested not to discuss the experiment with potential subjects. The entire procedure lasted approximately 25 minutes.

IV. RESULTS

Several analyses were done relating to word frequency, response times and syntactic structure of two-word responses using the Statistical Package for the Social Sciences (SPSS). These analyses were computed using all subjects, subjects by AVTYPES and subjects by AVTYPES and BLOCKS. A complete codebook (Appendix C) shows fully how each subject and the verbal responses, along with their respective reaction times, were classified for entry onto computer cards for statistical analysis.

Tables 1-5 show the absolute and relative frequencies of the verbal responses to each of the five sets of slides tested. Although it appears that there are many different responses in each category, several of the responses include the word or words which are presently written on the P-3C pilot's keyset panel. For example, under the variable labeled "Position" (Table 1) the first eight responses included some form or variation of the word position. Therefore, they comprised 93.3% of the total responses for both aviation groups under that variable. Using a similar analysis the following results were obtained: 87.8% of the responses incorporated variations of the word "track" in that category, 48.9% of the responses under the variable "correct" used a form of the word correct, 93.3% of the responses under the variable "center" utilized a variation

TABLE 1

VERBAL RESPONSES AND THEIR FREQUENCY TO SLIDE SET 1 (POSITION) FOR ALL SUBJECTS AND BY AVIATION TYPES

Responses For Slide Set Position	All Subjects		AVTYPE 1		AVTYPE 2	
	Frequency	Relative Frequency (Pct.)	Frequency	Relative Frequency (Pct.)	Frequency	Relative Frequency (Pct.)
Position	33	36.7	15	33.3	18	40.0
Display Position	7	7.8	5	11.1	2	4.4
Aircraft Position	28	31.1	18	40.0	10	22.2
Posit	6	6.7	3	6.7	3	6.7
Show Position	3	3.3			3	6.7
Present Position	2	2.2			2	4.4
Aircraft Posit	4	4.4	4	8.9		
Mark Position	1	1.1			1	2.2
Lat Long	3	3.3			3	6.7
Bearing	1	1.1			1	2.2
Fix	1	1.1			1	2.2
No Response	1	1.1			1	2.2
Total	90	100.0	45	100.0	45	100.0

TABLE 2

VERBAL RESPONSES AND THEIR FREQUENCY TO SLIDE SET 2 (TRACK) FOR ALL SUBJECTS AND BY AVIATION TYPES

Responses For Slide Set Track	All Subjects Frequency	Relative Freq. (Pct.)	AVTYPE 1 Frequency	Relative Freq. (Pct.)	AVTYPE 2 Freq.	Relative Freq. (Pct.)
Aircraft Track	46	51.1	34	75.6	12	26.7
Display Track	11	12.2	8	17.8	3	6.7
Track	11	12.2	2	4.4	9	20.0
Show Track	3	3.3			3	6.7
Ground Track	2	2.2			2	4.4
Track Aircraft	2	2.2	1	2.2	1	2.2
Trackline	2	2.2			2	4.4
Display Trackline	1	1.1			1	2.2
Track History	1	1.1			1	2.2
Mark Turn	1	1.1			1	2.2
Plot Turn	1	1.1			1	2.2
Right Turn	1	1.1			1	2.2
Bearing	2	2.2			2	4.4
Status	3	3.3			3	6.7
Drop Points	1	1.1			1	2.2
Mid Drop Point	1	1.1			1	2.2
Drop Midpoint	1	1.1			1	2.2
No Response	0	0.0			0	0.0
Total	90	100.0	45	100.0	45	100.0

TABLE 3

VERBAL RESPONSES AND THEIR FREQUENCY TO SLIDE SET 3 (CORRECT) FOR ALL SUBJECTS AND BY AVIATION TYPES

Responses For Slide Set Correct	All Subjects Frequency	All Subjects Relative Frequency (Pct.)	AVTYPE 1 Frequency	AVTYPE 1 Relative Frequency (Pct.)	AVTYPE 2 Frequency	AVTYPE 2 Relative Frequency (Pct.)
Aircraft Correct	27	30.0	24	53.3	3	6.7
Correct Aircraft	7	7.8	2	4.4	5	11.1
Correct Track	3	3.3	2	4.4	1	2.2
Correct Position	1	1.1			1	2.2
Correct	1	1.1			1	2.2
Correction	1	1.1			1	2.2
Correct Position	2	2.2			2	4.4
Correct Trackline	1	1.1			1	2.2
Slew Correction	1	1.1			1	2.2
Aircraft Slew	3	3.3	3	6.7		
Slew Left	2	2.2			2	4.4
Update Aircraft	6	6.7	1	2.2	5	11.1
Update	3	3.3			3	6.7
Update Position	2	2.2			2	4.4
Aircraft Plot	3	3.3			3	6.7
Aircraft Left	2	2.2			2	4.4
Displace Aircraft	3	3.3	3	6.7		

TABLE 3 (Continued)

Responses For Slide Set Correct	All Subjects Frequency	All Subjects Relative Frequency (Pct.)	AVTYPE 1 Frequency	AVTYPE 1 Relative Frequency (Pct.)	AVTYPE 2 Frequency	AVTYPE 2 Relative Frequency (Pct.)
Reposition Aircraft	3	3.3	3	6.7		
Relocate Aircraft	1	1.1			1	2.2
Relocate	1	1.1			1	2.2
Change	3	3.3			3	6.7
Mark On Top	3	3.3	3	6.7		
Mark On Top Seven	1	1.1	1	2.2		
Center	1	1.1			1	2.2
Reset	2	2.2			2	4.4
Slew Aircraft	5	5.6	2	4.4	3	6.7
No Response	2	2.2	1	2.2	1	2.2
Total	90	100.0	45	100.0	45	100.0

TABLE 4

VERBAL RESPONSES AND THEIR FREQUENCY TO SLIDE SET 4 (CENTER) FOR ALL SUBJECTS AND BY AVIATION TYPES

Responses For Slide Set Center	All Subjects Freq.	All Subjects Relative Freq. (Pct.)	AVTYPE 1 Freq.	AVTYPE 1 Relative Freq. (Pct.)	AVTYPE 2 Freq.	AVTYPE 2 Relative Freq. (Pct.)
Recenter Aircraft	17	18.9	14	31.1	3	6.7
Center Aircraft	26	28.9	14	31.1	12	26.7
Aircraft Center	18	20.0	10	22.2	8	17.8
Aircraft Recenter	5	5.6	2	4.4	3	6.7
Center	13	14.4	4	8.9	9	20.0
Center Display	2	2.2			2	4.4
Center Bug	2	2.2			2	4.4
Center Pipper	1	1.1			1	2.2
Shift Display	1	1.1			1	2.2
Aircraft Plot	2	2.2			2	4.4
Reposition	1	1.1	1	2.2		
No Response	2	2.2			2	4.4
Total	90	100.0	45	100.0	45	100.0

TABLE 5

VERBAL RESPONSES AND THEIR FREQUENCY TO SLIDE SET 5 (SCALE) FOR ALL SUBJECTS AND BY AVIATION TYPES

Responses For Slide Set Scale	All Subjects Freq.	All Subjects Relative Freq. (Pct.)	AVTYPE 1 Freq.	AVTYPE 1 Relative Freq. (Pct.)	AVTYPE 2 Freq.	AVTYPE 2 Relative Freq. (Pct.)
Increase Scale	24	26.7	14	31.1	10	22.2
Up Scale	30	33.3	27	60.0	3	6.7
Scale Up	3	3.3	1	2.2	2	4.4
Scale	3	3.3			3	6.7
Show Scale	1	1.1			1	2.2
Enlarge Scale	2	2.2			2	4.4
Scale Increase	3	3.3			3	6.7
Scale Change	3	3.3			3	6.7
Change Scale	3	3.3	1	2.2	2	4.4
Display Scale	1	1.1			1	2.2
Scale 64	7	7.8	2	4.4	5	11.1
Range Up	1	1.1			1	2.2
Buoy Range	2	2.2			2	4.4
Sonobuoy Range	1	1.1			1	2.2
Range Increase	1	1.1			1	2.2
Range Times 4	2	2.2			2	4.4
Enlarge	1	1.1			1	2.2
Up Two	2	2.2			2	4.4
No Response	0	0.0				
Total	90	100.0	45	100.0	45	100.0

of the word center, and 88.9% of the responses under the variable "scale" used a form of that word.

Tables 6-8 show the mean and standard deviation of the response times to each set of slides for the overall experiment in conjunction with BLOCKS 1-3. Through comparison of statistics in Tables 1-5 it can be demonstrated that the responses of AVTYPE 1 comprised a higher percentage of the variable words under consideration than those for AVTYPE 2. Likewise, it can be shown in Tables 6-8 that the response latencies for AVTYPE 1 were in all cases lower than those for AVTYPE 2.

A three way analysis of variance was performed due to the structure of the experimental design (Edwards, 1968). The results are shown in Table 9. The only significant effects ($P < .001$) are those of the main effects: AVTYPES, BLOCKS, and TASKS.

Duncan's Multiple Range Test (Edwards, 1968) was used (Tables 10 and 11) to investigate the differences existing among the means of the BLOCKS and the differences among the means of the TASKS. The underscored means do not differ significantly at a probability less than .001. A Range test was not performed on the differences between the means of the AVTYPES since there are only two means and the analysis of variance has already shown that the differences are significant ($P < .001$).

The difference between usage of one and two-word commands was investigated with the results shown in Table 12. The

TABLE 6

REACTION TIME STATISTICS TO EACH OF THE SLIDE SETS FOR ALL SUBJECTS WITH RESPECT TO THE OVERALL EXPERIMENT AND ALSO FOR BLOCKS 1-3

ALL SUBJECTS

SET	STATISTIC	Block 1	Block 2	Block 3	TOTAL
POSITION	MEAN	7.113	5.873	4.793	5.927
	STD. DEV.	3.704	3.845	3.108	3.653
TRACK	MEAN	4.900	4.513	4.193	4.536
	STD. DEV.	3.704	3.858	3.401	3.630
CORRECT	MEAN	8.133	6.553	5.180	6.622
	STD. DEV.	4.470	5.001	3.754	4.553
CENTER	MEAN	8.813	5.047	4.327	6.062
	STD. DEV.	5.092	2.846	2.560	4.140
SCALE	MEAN	4.980	3.627	3.340	3.982
	STD. DEV.	2.989	2.853	2.130	2.749
ALL SETS	MEAN	33.940	25.613	21.833	27.129
	STD. DEV.	14.943	13.842	12.522	14.565

TABLE 7

REACTION TIME STATISTICS TO EACH OF THE SLIDE SETS FOR AVTYPE 1 WITH RESPECT TO THE OVERALL EXPERIMENT AND ALSO FOR BLOCKS 1-3

		AVTYPE 1			
SET	STATISTIC	BLOCK 1	BLOCK 2	BLOCK 3	TOTAL
POSITION	MEAN	6.013	4.507	4.000	4.840
	STD. DEV.	3.239	2.317	2.392	2.759
TRACK	MEAN	3.507	2.800	2.920	3.076
	STD. DEV.	1.888	.796	2.071	1.673
CORRECT	MEAN	7.307	4.987	4.373	5.556
	STD. DEV.	4.157	4.714	3.124	4.160
CENTER	MEAN	6.547	3.693	3.787	4.676
	STD. DEV.	3.141	1.136	2.180	2.618
SCALE	MEAN	3.893	2.627	2.520	3.013
	STD. DEV.	1.994	.803	.684	1.420
ALL SETS	MEAN	27.267	18.613	17.600	21.160
	STD. DEV.	9.005	7.097	7.850	8.982

TABLE 8

REACTION TIME STATISTICS TO EACH OF THE SLIDE SETS FOR AVTYPE 2 WITH RESPECT TO THE OVERALL EXPERIMENT AND ALSO FOR BLOCKS 1-3

		AVTYPE 2			
SET	STATISTIC	BLOCK 1	BLOCK 2	BLOCK 3	TOTAL
POSITION	MEAN	8.213	7.240	5.587	7.013
	STD. DEV.	3.917	4.609	3.598	4.119
TRACK	MEAN	6.293	6.227	5.467	5.996
	STD. DEV.	4.549	4.890	4.025	4.415
CORRECT	MEAN	8.960	8.120	5.987	7.689
	STD. DEV.	4.759	4.933	4.248	4.721
CENTER	MEAN	11.080	6.400	4.867	7.449
	STD. DEV.	5.730	3.400	2.864	4.887
SCALE	MEAN	6.067	4.627	4.160	4.951
	STD. DEV.	3.465	3.751	2.737	3.369
ALL SETS	MEAN	40.613	32.613	26.067	33.098
	STD. DEV.	16.912	15.542	14.992	16.600

TABLE 9

ANALYSIS OF VARIANCE

RT
BY AVTYPE
BLOCK
TASKS

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	1548.412	7	221.202	18.340	0.000
AVTYPE	641.217	1	641.217	53.164	0.000
BLOCK	460.447	2	230.224	19.088	0.000
TASKS	446.748	4	111.687	9.260	0.000
2-WAY INTERACTIONS	197.606	14	14.115	1.170	0.295
AVTYPE BLOCK	27.417	2	13.708	1.137	0.322
AVTYPE TASKS	16.774	4	4.194	0.348	0.846
BLOCK TASKS	153.415	8	19.177	1.590	0.126
3-WAY INTERACTIONS	37.762	8	4.720	0.391	0.925
AVTYPE BLOCK TASKS	37.762	8	4.720	0.391	0.925
EXPLAINED	1783.781	29	61.510	5.100	0.000
RESIDUAL	5065.660	420	12.061		
TOTAL	6849.441	449	15.255		

450 CASES WERE PROCESSED.
0 CASES (0.0 Pct) WERE MISSING.

TABLE 10

DUNCAN'S MULTIPLE RANGE TEST FOR BLOCKS 1-3

BLOCKS		3	2	1	SHORTEST SIGNIFICANT RANGES
	MEANS	21.833	25.613	33.940	$\alpha = .001$
3	21.833		3.780	12.107	$R_2 = 1.438$
2	25.613			8.327	$R_3 = 1.483$

		3	2	1	

TABLE 11

DUNCAN'S MULTIPLE RANGE TEST FOR TASKS 1-5

TASKS		SCALE	TRACK	POSITION	CENTER	CORRECT	SHORTEST SIGNIFICANT RANGES
	MEANS	3.982	4.536	5.927	6.062	6.622	α = .001
SCALE	3.982		.554	1.945	2.080	2.640	R_2 = 1.933
TRACK	4.536			1.391	1.526	2.086	R_3 = 1.996
POSI-TION	5.927				.135	.695	R_4 = 2.039
CENTER	6.062					.560	R_5 = 2.072

SCALE TRACK POSITION CENTER CORRECT

TABLE 12

ONE WORD VS. TWO WORD RESPONSES

	ONE WORD COMMANDS			TWO WORD COMMANDS		
	FREQ.	MEAN RESPONSE TIME	STD. DEV.	FREQ.	MEAN RESPONSE TIME	STD. DEV.
AVTYPE 1	25	4.08 sec.	1.87 sec.	199	4.14 sec.	2.71 sec.
AVTYPE 2	63	5.94 sec.	3.69 sec.	159	6.65 sec.	4.25 sec.
ALL SUBJECTS	88	5.41 sec.	3.38 sec.	358	5.25 sec.	3.69 sec.

reason for this analysis was to determine if there was a preference by the subjects in using a one or two-word command. To test the preference for either a one or two-word command the Binomial Test (Siegel, 1956) was used since all the observations from the sample population fell into either one of two discrete classifications. The null hypothesis tested was that no difference existed between the probability of either using a one or two-word command (i.e., H_o: $p_1 = p_2 = \frac{1}{2}$). Since the sample sizes were larger than 25, normal approximations of the binomial test were used. The null hypothesis was rejected for both aviation types at the .001 level of significance and the conclusion was that the preference for a one or two-word command was not equally likely. By observing the data in Table 12 a preference is indicated in favor of the two-word commands. The difference between the mean response times of one and two-word commands was also analyzed since verbal reaction times may be critical in the pilot-voice machine interface. To avoid the restrictions of the t-test for testing the differences between two means, the Normal test (Freund, 1971) was used since the sample size was large enough for the central limit theorem to be invoked. The hypothesis being tested was that the mean response time for one-word commands would equal the mean response time for two-word commands (i.e., H_o: $u_1 - u_2 = 0$). The null hypothesis could not be rejected at the .001 level of significance for both aviation types and it is therefore

concluded that the mean response times for one and two-word commands are the same.

Since the subjects had an overwhelming preference for two-word commands an analysis of the syntax structure of the two-word commands was performed. This was done utilizing the same logic as the one-word versus two-word command analysis, and thus promotes compatability between the human operator and the machine insofar as syntax structure is concerned.

The two-word commands were divided into two groups. The first group was called Command Phrases since the first word was a command verb and the second word was the noun on which the command verb was acting (Appendix D). The second group was called Descriptive Phrases because the first word modified the second word and merely described changes on the pilot's visual display (Appendix E). The frequency and response times for these two groups are shown in Table 13.

A Binomial test (Siegel, 1956) was used to test the hypothesis that there was no preference between using either a command phrase or descriptive phrase (i.e., H_o: $p_1 = p_2 = \frac{1}{2}$). Normal approximations of the Binomial test were used since the sample sizes were larger than 25 for both aviation types. The null hypothesis was rejected for AVTYPE 1 at the .001 level of significance but was not rejected for AVTYPE 2 at the same level of significance. It is therefore concluded that there is an AVTYPE 1 preference in syntactic structure but not for AVTYPE 2.

TABLE 13

COMMAND PHRASES VS. DESCRIPTIVE PHRASES

	COMMAND PHRASES			DESCRIPTIVE PHRASES		
	FREQ.	MEAN RESPONSE TIME	STD. DEV.	FREQ.	MEAN RESPONSE TIME	STD. DEV.
AVTYPE 1	75	4.71 sec.	3.13 sec.	124	3.79 sec.	2.37 sec.
AVTYPE 2	84	7.11 sec.	4.67 sec.	75	6.13 sec.	3.70 sec.
ALL SUBJECTS	159	5.98 sec.	4.18 sec.	199	4.67 sec.	3.15 sec.

V. DISCUSSION

Due to the familiarity of AVTYPE 1 with the P-3C aircraft it was not unexpected that their verbal responses comprised a higher percentage of the variable words (titles of the slide sets) and responded with lower latency times than those for AVTYPE 2. These results are in keeping with Gagné (1970) who stated that recognition is an easier task than recall or other associative processes and therefore yields higher remembering scores.

In considering the preference of two-word commands over one-word commands it was not unexpected that AVTYPE 1 had a strong preference for two-word commands since all the keyset functions on the P-3C pilot's keyset panel are two or more words. AVTYPE 2's preference for two-word commands can only be attributed to natural verbal behavior patterns. Since both groups preferred two-word commands and the response latencies were equal for one and two-word commands then it seems reasonable to conclude that two-word commands have a definite advantage over one-word commands. The voice recognition machine also has a high recognition accuracy when long words or multiple words are used.

In the last part of the analysis dealing with syntactic structure in human verbal behavior some interesting differences arose. For AVTYPE 1 the null hypothesis, that there existed no preference between command and descriptive

phrases, was rejected. However, for AVTYPE 2 the same null hypothesis was not rejected. The results for AVTYPE 1 were not unexpected since three out of the five (60%) P-3C keyset functions under investigation were descriptive phrases and the other two were command phrases. The data verify this result since 62% of the two-word verbal phrases elicited by AVTYPE 1 were descriptive phrases. It is therefore concluded that AVTYPE 1 was biased in their responses and AVTYPE 2 was naive as originally hypothesized in the statement of the problem.

VI. RECOMMENDATIONS

Based upon the results and conclusions presented in this thesis it is felt that the following recommendations should be incorporated into the machine voice recognition system in order to make the interface between human and machine more viable. Because the predominance of verbal responses clustered around the nomenclature on the P-3C keyset panel then the first approximation to the needed voice command vocabulary should be made up of the present keyset phrases. Since two-word commands were preferred by both aviation types then this preference should be incorporated in present voice systems and future design considerations. Since AVTYPE 2 showed no preference as far as verbal syntactic structure was concerned either command phrases or descriptive phrases could be incorporated in the voice machine vocabulary.

As future personnel enter the aviation community their verbal behavior patterns will have to be tested in order to modify existing voice command systems to produce the optimum interface between human and machine. As future hardware systems are produced and developed some of the present machine restrictions will inevitably be reduced making the human-machine interface as natural as the human-human interface.

APPENDIX A

SUBJECT QUESTIONNAIRE

1) Name ______________________________

2) Rank ______________________________

3) Service ___________________________

4) P3-C Operational experience?

(Check) Yes ______ No ______

If yes: (a) Position on crew _______________

(b) Total flight hours P3-C ________

5) Latest Operational aircraft flown and position, if not P3-C

(a) Aircraft type __________________

(b) Position on crew _______________

6) Comments (fill in at completion of experiment)

Name of Subject ____________________

SUBJECT DATA SHEET

Response number	Verbal response	Timing (in sec)
1.	____________	____________
2.	____________	____________
3.	____________	____________
4.	____________	____________
5.	____________	____________
6.	____________	____________
7.	____________	____________
8.	____________	____________
9.	____________	____________
10.	____________	____________
11.	____________	____________
12.	____________	____________
13.	____________	____________
14.	____________	____________
15.	____________	____________

APPENDIX B

TAPED INSTRUCTIONS FOR TEST SUBJECTS

Hello! Today you will be participating in an experiment to determine a partial vocabulary needed for a computer voice command system being developed at Nasa Ames Research Center. This experiment is being run to determine the most natural words or phrases that a pilot would use to command information on a visual display. These words and phrases would then be utilized in a computer voice command system to replace the manual keyset functions which now exist to display pertinent information on the pilot's display. Please listen carefully since most of the information presented on this taped briefing should help you identify what will be happening during the experiment.

You will be presented with 15 sets of slides. The first slide of each set will be labeled at the top with the word "BEFORE" and will represent what the pilot initially sees. You will then see one or more slides to portray what the pilot would see after pressing the desired key. The last slide of each set will be labeled at the top with the word "AFTER" to signify the end of that set and to key you to give your verbal response.

The slides depict a pilot's visual perspective of what the aircraft is actually doing in a horizontal plane. The

display can also show other pertinent information which will be fully explained. (SLIDE ONE)

On the right side of the pilot's display is a label called "MILES FROM MIDDLE TO EDGE OF DISPLAY". The mileage displayed here will either be 2, 4, 8, 16, 32, 64, or 128.

On the top of the display is an area for computer generated alerts which we will not be dealing with. On the left side of the display the pilot can be presented with the aircraft's altitude and at the bottom labeled "CUEING AREA" the pilot can be presented with information such as where the aircraft is presently located in degrees of latitude and longitude. (SLIDE TWO) This slide represents what the pilot actually sees, except for the arrow. The pilot can move the aircraft symbol or move a sonobuoy, for our purposes labeled #7, if either is determined to be in the wrong location electronically. The pilot can also show where the aircraft has been by displaying small + characters behind the aircraft symbol.

As previously mentioned, the first slide of each set will be labeled "BEFORE". You will then see one or more slides to represent what the pilot would see after pressing the appropriate key. The last slide of each set will be labeled "AFTER" to signify the end of that set and to key you to give your one or two-word command which you would use to represent what has changed on the display. There will be one blank slide between each set of slides. You will

see each slide for 10 seconds. Your verbal response will be timed when the slide labeled "AFTER" first appears in front of you. No response should be made until you see the slide labeled "AFTER". You will see the slide labeled "AFTER" for 10 seconds and then a blank slide for 10 seconds giving you a maximum time of 20 seconds to give your one or two-word command.

The slides will always show the aircraft symbol and the sonobuoy labeled #7. The reason for the sonobuoy #7 is to give you a perspective with the aircraft symbol when movement is involved. For example, if the mileage from the center to the edge of the display is changed then the aircraft symbol and the sonobuoy #7 may appear to be farther apart or closer together.

There will also be a small arrow on all the slides pointing to the changing part of the display which your response should be centered around.

Before starting the experiment there will be one example. (SLIDE THREE) In front of you is a slide labeled "BEFORE" with the aircraft symbol and the sonobuoy #7. You will see every slide for 10 seconds. (SLIDE FOUR) Now the slide labeled "AFTER" is shown with the arrow pointing to the # 5000. Your verbal command might be altitude or aircraft altitude.

Remember, your verbal response will be timed when the slide labeled "AFTER" first appears in front of you and no response should be made until you see the slide labeled

"AFTER". If you have no idea at all what is happening during a set of slides do not say anything.

Some of the sets of slides will be repeated. If you recognize a set of slides that you have seen before give your best response whether it be the same or different than your previous response to that set of slides.

When you give your response to a set of slides please say only your one or two-word command.

You do not need to press any buttons on the intercom system. When the experiment is done I will notify you on the intercom system.

Please do not discuss the experiment with anyone who may be a future subject since you may bias future subjects with the vocabulary you felt was appropriate during the experiment.

Are there any questions?

APPENDIX C

CODEBOOK

COLS	VARIABLE NAME	VARIABLE DESCRIPTION + CODES
1-2	ID	Subject ID # (1-30)
3	AVTYPE	Flying Experience 1. P3C Experience 2. Non P3C Experience
4	BLOCK	Trial Block # 1. Trials 1-5 2. Trials 6-10 3. Trials 11-15
5-6	POSITION	Response to first slide of Blocks 1,2,3 respectively 1. POSITION 2. DISPLAY POSITION 3. A/C POSITION 4. POSIT 5. SHOW POSITION 6. PRESENT POSITION 7. A/C POSIT 8. MARK POSITION 9. LAT LONG 10. BEARING 11. FIX 99. NO RESPONSE
7-8	TRACK	Response to 2nd slide of Blocks 1,2,3, respectively 1. A/C TRACK 2. DISPLAY TRACK 3. TRACK 4. SHOW TRACK 5. GROUND TRACK 6. TRACK A/C 7. TRACKLINE 8. DISPLAY TRACKLINE 9. TRACK HISTORY 10. MARK TURN 11. PLOT TURN 12. RIGHT TURN 13. BEARING 14. STATUS 15. DROP POINTS 16. MID DROP POINT 17. DROP MIDPOINT 99. NO RESPONSE

COLS	VARIABLE NAME	VARIABLE DESCRIPTION + CODES
10	CORRECT	Response to 3rd slide of Blocks 1,2,3 respectively

1. A/C CORRECT
2. CORRECT A/C
3. CORRECT TRACK
4. CORRECT POSITION
5. CORRECT
6. CORRECTION
7. CORRECT POSITION
8. CORRECT TRACKLINE
9. SLEW CORRECTION
10. A/C SLEW
11. SLEW A/C
12. SLEW LEFT
13. UPDATE A/C
14. UPDATE
15. UPDATE POSITION
16. A/C PLOT
17. A/C LEFT
18. DISPLACE A/C
19. REPOSITION A/C
20. RELOCATE A/C
21. RELOCATE
22. CHANGE
23. MARK ON TOP
24. MARK ON TOP SEVEN
25. CENTER
26. RESET
99. NO RESPONSE

COLS	VARIABLE NAME	VARIABLE DESCRIPTION + CODES
11-12	CENTER	Responses to 4th slide of Blocks 1,2,3 respectively

1. RECENTER A/C
2. CENTER A/C
3. A/C CENTER
4. A/C RECENTER
5. CENTER
6. CENTER DISPLAY
7. CENTER BUG
8. CENTER PIPPER
9. SHIFT DISPLAY
10. A/C PLOT
11. REPOSITION
99. NO RESPONSE

COLS	VARIABLE NAME	VARIABLE DESCRIPTION + CODES
13-14	SCALE	Response to 5th slide of Blocks 1,2,3 respectively 1. INCREASE SCALE 2. UP SCALE 3. SCALE UP 4. SCALE 5. SHOW SCALE 6. ENLARGE SCALE 7. SCALE INCREASE 8. SCALE CHANGE 9. CHANGE SCALE 10. DISPLAY SCALE 11. SCALE 64 12. RANGE UP 13. BUOY RANGE 14. SONOBUOY RANGE 15. RANGE INCREASE 16. RANGE TIME 4 17. ENLARGE 18. UP TWO 99. NO RESPONSE
15-17	RTPOSIT	Reaction times for responses 1,6,11 in secs and nearest 1/5 sec. (F 3.1)
18-20	RTTRACK	Reaction times for responses 2,7,12 in secs and nearest 1/5 sec (F 3.1)
21-23	RTCORECT	Reaction times for responses 3,8,13 in secs and nearest 1/5 sec (F 3.1)
24-26	RTCENTER	Reaction times for responses 4,9,14 in secs and nearest 1/5 sec (F 3.1)
27-29	RTSCALE	Reaction times for responses 5,10,15 in secs and nearest 1/5 sec (F 3.1)
40	TASKS	NAMES OF TASKS 1. POSITION 2. TRACK 3. CORRECT 4. CENTER 5. SCALE

APPENDIX D

COMMAND PHRASES

1. Display Position
2. Show Position
3. Present Position
4. Mark Position

5. Display Track
6. Show Track
7. Track Aircraft
8. Display Trackline
9. Mark Turn
10. Plot Turn
11. Drop Midpoint

12. Correct Aircraft
13. Correct Track
14. Correct Position
15. Correct Trackline
16. Slew Correction
17. Slew Aircraft
18. Slew Left
19. Update Aircraft
20. Update Position
21. Displace Aircraft
22. Reposition Aircraft
23. Relocate Aircraft
24. Mark on Top
25. Mark on Top 7

26. Recenter Aircraft
27. Center Aircraft
28. Center Display
29. Center Bug
30. Center Pipper
31. Shift Display

32. Increase Scale
33. Up Scale
34. Show Scale
35. Enlarge Scale
36. Change Scale
37. Display Scale

APPENDIX E

DESCRIPTIVE PHRASES

1. Aircraft Position
2. Aircraft Posit
3. Lat Long

4. Aircraft Track
5. Ground Track
6. Track History
7. Right Turn
8. Drop Points
9. Mid Droppoint

10. Aircraft Correct
11. Aircraft Slew
12. Aircraft Plot
13. Aircraft Left

14. Aircraft Center
15. Aircraft Recenter
16. Aircraft Plot

17. Scale Up
18. Scale Increase
19. Scale Change
20. Scale 64
21. Range Up
22. Buoy Range
23. Sonobuoy Range
24. Range Increase
25. Range Times Four
26. Up Two

APPENDIX F

SUBJECT DATA SHEET

SUBJECT NO. 1   AVTYPE 1

Response number	Verbal response	Timing (in sec)
1.	Display Position	5.2
2.	Aircraft Track	2.6
3.	Aircraft Correct	6.4
4.	Recenter Aircraft	3.2
5.	Increase Scale	3.0
6.	Aircraft Correct	2.0
7.	Display Track	2.6
8.	Display Position	4.6
9.	Increase Scale	2.6
10.	Recenter Aircraft	4.0
11.	Display Track	2.0
12.	Increase Scale	2.6
13.	Display Position	4.0
14.	Recenter Aircraft	3.2
15.	Aircraft Correct	2.6

SUBJECT DATA SHEET

SUBJECT NO. 2 AVTYPE 1

Response number	Verbal Response	Timing (in sec)
1.	Position	3.0
2.	Aircraft Track	1.8
3.	Displace Aircraft	3.4
4.	Recenter Aircraft	11.0
5.	Up Scale	2.0
6.	Displace Aircraft	2.0
7.	Aircraft Track	1.8
8.	Position	2.4
9.	Up Scale	1.8
10.	Recenter Aircraft	2.0
11.	Aircraft Track	1.0
12.	Up Scale	1.4
13.	Position	1.0
14.	Recenter Aircraft	1.4
15.	Displace Aircraft	1.6

SUBJECT DATA SHEET

SUBJECT NO. 3   AVTYPE 1

Response number	Verbal Response	Timing (in sec)
1.	Position	11.4
2.	Display Track	3.4
3.	Aircraft Correct	4.4
4.	Center Aircraft	4.8
5.	Up Scale	3.4
6.	Aircraft Correct	3.0
7.	Display Track	3.0
8.	Position	4.6
9.	Up Scale	2.6
10.	Center Aircraft	3.0
11.	Track	2.0
12.	Up Scale	2.0
13.	Position	3.6
14.	Center Aircraft	3.0
15.	Correct Aircraft	2.8

SUBJECT DATA SHEET

SUBJECT NO. 4 AVTYPE 1

Response number	Verbal response	Timing (in sec)
1.	Position	7.4
2.	Aircraft Track	5.0
3.	Aircraft Correct	9.8
4.	Center Aircraft	9.4
5.	Up Scale	3.4
6.	Aircraft Correct	8.2
7.	Aircraft Track	3.4
8.	Aircraft Position	6.0
9.	Up Scale	2.4
10.	Center Aircraft	4.4
11.	Aircraft Track	4.0
12.	Up Scale	2.4
13.	Aircraft Position	11.2
14.	Center Aircraft	9.0
15.	Aircraft Correct	3.8

SUBJECT DATA SHEET

SUBJECT NO. 5 AVTYPE 1

Response number	Verbal response	Timing (in sec)
1.	Display Position	13.6
2.	Aircraft Track	2.4
3.	Aircraft Slew	5.4
4.	Aircraft Center	8.4
5.	Change Scale	10.0
6.	Aircraft Slew	4.2
7.	Aircraft Track	2.0
8.	Aircraft Position	9.8
9.	Increase Scale	2.4
10.	Aircraft Center	4.0
11.	Aircraft Track	9.2
12.	Increase Scale	2.6
13.	Aircraft Position	4.2
14.	Aircraft Center	2.4
15.	Aircraft Slew	3.0

SUBJECT DATA SHEET

SUBJECT NO. 6 AVTYPE 1

Response number	Verbal response	Timing (in sec)
1.	Position	4.0
2.	Aircraft Track	4.8
3.	Aircraft Correct	15.6
4.	Center Aircraft	10.2
5.	Up Scale	4.0
6.	Mark on Top	3.8
7.	Aircraft Track	2.6
8.	Position	3.6
9.	Up Scale	2.8
10.	Center	4.4
11.	Aircraft Track	2.0
12.	Up Scale	2.2
13.	Position	1.8
14.	Center	3.2
15.	Mark on Top	2.2

SUBJECT DATA SHEET

SUBJECT NO. 7   AVTYPE 1

Response number	Verbal response	Timing (in sec)
1.	Aircraft Position	3.4
2.	Aircraft Track	3.2
3.	Aircraft Correct	3.8
4.	Center Aircraft	4.6
5.	Up Scale	3.4
6.	Aircraft Correct	3.4
7.	Aircraft Track	3.2
8.	Aircraft Position	3.0
9.	Up Scale	2.8
10.	Center Aircraft	4.2
11.	Aircraft Track	3.0
12.	Up Scale	3.2
13.	Aircraft Position	4.4
14.	Center Aircraft	5.0
15.	Aircraft Correct	3.4

SUBJECT DATA SHEET

SUBJECT NO. 8 AVTYPE 1

Response number	Verbal response	Timing (in sec)
1.	Position	5.2
2.	Display Track	2.0
3.	Aircraft Correct	3.4
4.	Reposition	8.2
5.	Up Scale	2.4
6.	Aircraft Correct	3.0
7.	Display Track	3.0
8.	Position	3.2
9.	Up Scale	2.4
10.	Aircraft Center	3.0
11.	Display Track	3.2
12.	Up Scale	2.8
13.	Position	3.0
14.	Aircraft Center	3.2
15.	Aircraft Correct	3.4

SUBJECT DATA SHEET

SUBJECT NO. 9 AVTYPE 1

Response number	Verbal response	Timing (in sec)
1.	Position	4.0
2.	Track	4.6
3.	Aircraft Correct	12.2
4.	Recenter Aircraft	5.8
5.	Increase Scale	5.0
6.	Aircraft Correct	4.8
7.	Aircraft Track	3.0
8.	Posit	4.2
9.	Increase Scale	2.6
10.	Aircraft Center	3.2
11.	Aircraft Track	1.8
12.	Increase Scale	2.6
13.	Posit	3.6
14.	Aircraft Center	3.0
15.	Aircraft Correct	1.8

SUBJECT DATA SHEET

SUBJECT NO. 10   AVTYPE 1

Response number	Verbal response	Timing (in sec)
1.	Aircraft Position	5.8
2.	Aircraft Track	1.6
3.	Aircraft Correct	4.6
4.	Recenter Aircraft	4.6
5.	Up Scale	2.4
6.	Aircraft Correct	1.6
7.	Aircraft Track	1.6
8.	Aircraft Position	2.4
9.	Up Scale	1.8
10.	Aircraft Recenter	3.8
11.	Aircraft Track	1.0
12.	Up Scale	1.6
13.	Aircraft Position	2.6
14.	Aircraft Recenter	2.8
15.	Aircraft Correct	3.0

SUBJECT DATA SHEET

SUBJECT NO. 11   AVTYPE 1

Response number	Verbal response	Timing (in sec)
1.	Aircraft Position	1.6
2.	Aircraft Track	1.8
3.	Aircraft Correct	3.2
4.	Recenter Aircraft	2.4
5.	Increase Scale	1.8
6.	Aircraft Correct	2.6
7.	Aircraft Track	2.0
8.	Aircraft Position	1.8
9.	Increase Scale	1.8
10.	Recenter Aircraft	1.8
11.	Aircraft Track	1.6
12.	Increase Scale	1.8
13.	Aircraft Position	1.6
14.	Recenter Aircraft	1.8
15.	Aircraft Correct	1.6

SUBJECT DATA SHEET

SUBJECT NO. 12 AVTYPE 1

Response number	Verbal response	Timing (in sec)
1.	Display Position	5.4
2.	Aircraft Track	3.6
3.	Mark on Top	9.2
4.	Recenter Aircraft	3.8
5.	Scale 64	3.2
6.	No Response	20.0
7.	Aircraft Track	3.0
8.	Aircraft Posit	5.8
9.	Scale 64	2.0
10.	Recenter Aircraft	3.0
11.	Display Track	3.0
12.	Scale Up	3.4
13.	Aircraft Posit	4.8
14.	Recenter Aircraft	2.2
15.	Mark on Top Seven	6.4

SUBJECT DATA SHEET

SUBJECT NO. 13   AVTYPE 1

Response number	Verbal response	Timing (in sec)
1.	Position	4.4
2.	Aircraft Track	2.8
3.	Correct Track	9.0
4.	Center	3.6
5.	Up Scale	5.0
6.	Correct Track	2.6
7.	Aircraft Track	2.4
8.	Aircraft Position	2.6
9.	Up Scale	5.0
10.	Center	3.2
11.	Aircraft Track	1.8
12.	Up Scale	2.2
13.	Aircraft Position	3.6
14.	Center Aircraft	2.8
15.	Correct Aircraft	9.0

SUBJECT DATA SHEET

SUBJECT NO. 14   AVTYPE 1

Response number	Verbal response	Timing (in sec)
1.	Aircraft Position	6.6
2.	Aircraft Track	9.0
3.	Reposition Aircraft	4.8
4.	Center Aircraft	12.4
5.	Increase Scale	5.0
6.	Reposition Aircraft	4.0
7.	Aircraft Track	4.6
8.	Aircraft Position	4.8
9.	Increase Scale	3.0
10.	Center Aircraft	5.4
11.	Aircraft Track	3.0
12.	Increase Scale	3.2
13.	Aircraft Position	4.6
14.	Center Aircraft	7.2
15.	Reposition Aircraft	9.8

SUBJECT DATA SHEET

SUBJECT NO. 15 AVTYPE 1

Response number	Verbal response	Timing (in sec)
1.	Posit	9.2
2.	Aircraft Track	4.0
3.	Slew Aircraft	14.4
4.	Aircraft Center	5.8
5.	Up Scale	4.4
6.	Slew Aircraft	9.6
7.	Track Aircraft	3.8
8.	Aircraft Posit	8.8
9.	Up Scale	3.4
10.	Aircraft Center	6.0
11.	Aircraft Track	5.2
12.	Up Scale	3.8
13.	Aircraft Posit	6.0
14.	Aircraft Center	6.6
15.	Update Aircraft	11.0

SUBJECT DATA SHEET

SUBJECT NO. 16   AVTYPE 2

Response number	Verbal response	Timing (in sec)
1.	Position	6.0
2.	Aircraft Track	2.2
3.	Slew Aircraft	5.0
4.	Aircraft Center	5.6
5.	Increase Scale	2.0
6.	Aircraft Left	2.8
7.	Aircraft Track	2.0
8.	Position	3.6
9.	Increase Scale	2.0
10.	Aircraft Center	3.0
11.	Aircraft Track	2.2
12.	Increase Scale	2.6
13.	Position	2.4
14.	Aircraft Center	2.8
15.	Aircraft Left	3.2

SUBJECT DATA SHEET

SUBJECT NO. 17 AVTYPE 2

Response number	Verbal response	Timing (in sec)
1.	Position	3.0
2.	Track	3.0
3.	Aircraft Plot	3.6
4.	Aircraft Plot	11.6
5.	Scale	4.6
6.	Aircraft Plot	2.4
7.	Track	1.8
8.	Position	3.8
9.	Scale	2.2
10.	Aircraft Plot	9.6
11.	Track	3.4
12.	Scale	2.8
13.	Position	2.2
14.	Aircraft Center	5.8
15.	Aircraft Plot	4.0

SUBJECT DATA SHEET

SUBJECT NO. 18   AVTYPE 2

Response number	Verbal response	Timing (in sec)
1.	Show Position	12.4
2.	Show Track	5.2
3.	No Response	20.0
4.	No Response	20.0
5.	Display Scale	6.0
6.	Correct Position	16.0
7.	Show Track	8.4
8.	Show Position	11.4
9.	Change Scale	16.0
10.	Center Aircraft	14.0
11.	Show Track	4.2
12.	Show Scale	4.2
13.	Show Position	5.4
14.	Center Aircraft	6.4
15.	Correct Position	11.6

SUBJECT DATA SHEET

SUBJECT NO. 19   AVTYPE 2

Response number	Verbal response	Timing (in sec)
1.	Bearing	10.0
2.	Bearing	10.0
3.	Correction	8.6
4.	Center	8.6
5.	Enlarge	4.4
6.	Correct	6.6
7.	Bearing	3.8
8.	No Response	20.0
9.	Enlarge Scale	2.2
10.	Center	3.2
11.	Track Aircraft	2.8
12.	Enlarge Scale	2.8
13.	Display Position	3.2
14.	Center Aircraft	2.0
15.	Correct Aircraft	2.8

SUBJECT DATA SHEET

SUBJECT NO. 20 AVTYPE 2

Response number	Verbal response	Timing (in sec)
1.	Position	11.6
2.	Right Turn	16.2
3.	Reset	12.6
4.	Center	13.6
5.	Scale Up	15.6
6.	Slew Left	15.4
7.	Plot Turn	14.4
8.	Position	13.6
9.	Scale Up	6.8
10.	Aircraft Center	12.8
11.	Mark Turn	15.0
12.	Scale Increase	13.4
13.	Mark Position	14.0
14.	Aircraft Center	13.6
15.	Slew Left	14.2

SUBJECT DATA SHEET

SUBJECT NO. 21   AVTYPE 2

Response number	Verbal response	Timing (in sec)
1.	Position	3.4
2.	Trackline	2.4
3.	Correct Position	7.0
4.	Center Pipper	9.0
5.	Range Up	6.2
6.	Correct Track	8.8
7.	Trackline	15.8
8.	Position	4.4
9.	Up Two	10.4
10.	Center Bug	3.8
11.	Display Trackline	6.0
12.	Up Two	3.0
13.	Display Position	3.8
14.	Center Bug	3.2
15.	Correct Trackline	4.0

SUBJECT DATA SHEET

SUBJECT NO. 22 AVTYPE 2

Response number	Verbal response	Timing (in sec)
1.	Lat Long	8.8
2.	Ground Track	5.2
3.	Slew Correction	10.6
4.	Shift Display	15.0
5.	Increase Scale	5.8
6.	Update Aircraft	14.0
7.	Ground Track	3.8
8.	Lat Long	4.4
9.	Increase Scale	4.0
10.	Center Aircraft	4.6
11.	Display Track	4.0
12.	Increase Scale	3.6
13.	Lat Long	5.0
14.	Center Aircraft	5.8
15.	Correct Aircraft	4.8

SUBJECT DATA SHEET

SUBJECT NO. 23   AVTYPE 2

Response number	Verbal response	Timing (in sec)
1.	Posit	8.8
2.	Track	2.0
3.	Correct Aircraft	10.2
4.	Center Aircraft	5.4
5.	Sonobuoy Range	6.4
6.	Correct Aircraft	3.4
7.	Track	2.4
8.	Posit	5.8
9.	Buoy Range	5.2
10.	Center Aircraft	4.6
11.	Track	2.0
12.	Buoy Range	2.8
13.	Posit	3.4
14.	Center Aircraft	4.4
15.	Correct Aircraft	2.2

SUBJECT DATA SHEET

SUBJECT NO. 24   AVTYPE 2

Response number	Verbal response	Timing (in sec)
1.	Fix	5.6
2.	Track History	3.0
3.	Reset	3.6
4.	Center	5.2
5.	Increase Scale	3.0
6.	Center	5.2
7.	Display Track	4.0
8.	Position	5.4
9.	Increase Scale	3.2
10.	Center	5.6
11.	Display Track	4.0
12.	Increase Scale	2.6
13.	Position	4.6
14.	Center	4.8
15.	Slew Aircraft	8.0

SUBJECT DATA SHEET

SUBJECT NO. 25   AVTYPE 2

Response number	Verbal response	Timing (in sec)
1.	Aircraft Position	12.0
2.	Aircraft Track	14.6
3.	Relocate	14.2
4.	Center Display	18.8
5.	Change Scale	8.2
6.	Relocate Aircraft	15.8
7.	Aircraft Track	4.2
8.	Aircraft Position	7.4
9.	Scale 64	4.8
10.	Center Display	6.6
11.	Aircraft Track	4.8
12.	Scale 64	3.4
13.	Aircraft Position	8.4
14.	Aircraft Center	7.2
15.	Slew Aircraft	14.8

SUBJECT DATA SHEET

SUBJECT NO. 26 AVTYPE 2

Response number	Verbal response	Timing (in sec)
1.	Position	7.4
2.	Status	10.0
3.	Change	9.6
4.	Center	3.6
5.	Scale 64	5.0
6.	Change	6.4
7.	Status	10.2
8.	Position	5.4
9.	Scale 64	5.8
10.	Center	5.2
11.	Status	6.2
12.	Scale 64	5.0
13.	Position	4.0
14.	Center	4.2
15.	Change	3.4

SUBJECT DATA SHEET

SUBJECT NO. 27   AVTYPE 2

Response number	Verbal response	Timing (in sec)
1.	Position	2.8
2.	Track	2.8
3.	Update Position	3.4
4.	No Response	20.0
5.	Scale Change	4.0
6.	Update Position	4.0
7.	Track	1.8
8.	Present Position	3.0
9.	Scale Change	3.0
10.	Center Aircraft	5.2
11.	Track	2.2
12.	Scale Change	4.4
13.	Present Position	3.2
14.	Center Aircraft	2.6
15.	Update Aircraft	3.0

SUBJECT DATA SHEET

SUBJECT NO. 28 AVTYPE 2

Response number	Verbal response	Timing (in sec)
1.	Position	6.0
2.	Aircraft Track	4.0
3.	Aircraft Correct	4.6
4.	Aircraft Recenter	4.4
5.	Increase Scale	3.6
6.	Aircraft Correct	5.2
7.	Aircraft Track	2.6
8.	Aircraft Position	4.6
9.	Scale Increase	2.6
10.	Aircraft Recenter	3.2
11.	Aircraft Track	2.2
12.	Scale Increase	3.2
13.	Aircraft Position	3.0
14.	Aircraft Recenter	2.4
15.	Aircraft Correct	2.2

SUBJECT DATA SHEET

SUBJECT NO. 29 AVTYPE 2

Response number	Verbal response	Timing (in sec)
1.	Aircraft Position	8.8
2.	Aircraft Track	8.0
3.	Update Aircraft	13.6
4.	Recenter Aircraft	14.4
5.	Up Scale	4.8
6.	Update Aircraft	10.0
7.	Aircraft Track	5.0
8.	Aircraft Position	8.6
9.	Up Scale	2.2
10.	Recenter Aircraft	6.2
11.	Aircraft Track	11.0
12.	Up Scale	2.4
13.	Aircraft Position	10.0
14.	Recenter Aircraft	4.0
15.	Update Aircraft	5.4

SUBJECT DATA SHEET

SUBJECT NO. 30 AVTYPE 2

Response number	Verbal response	Timing (in sec)
1.	Position	16.6
2.	Drop Points	5.8
3.	Update	7.8
4.	Aircraft Center	11.0
5.	Range Increase	11.4
6.	Update	5.8
7.	Drop Midpoint	13.2
8.	Aircraft Position	7.2
9.	Range Times Four	8.4
10.	Center Aircraft	8.4
11.	Mid Droppoint	12.0
12.	Range Times Four	3.8
13.	Aircraft Position	11.2
14.	Center Aircraft	3.8
15.	Update	6.2

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